Industria: Jurnal Teknologi dan Manajemen Agroindustri
Volume 9 No 3: 195-202 (2020)

Industria: Jurnal Teknologi dan Manajemen Agroindustri
http://www.industria.ub.ac.id
ISSN 2252-7877 (Print) ISSN 2548-3582 (Online)
https://doi.org/10.21776/ub.industria.2020.009.03.4

Analysis on Product Quality of Semi Refined Carrageenan using Six Sigma and Cost of Poor Quality

Analisis Kualitas Produk Semi Refined Carrageenan *dengan Metode* Six Sigma *dan* Cost of Poor Quality

Syamsul Bahri, Fachriah Nur Rahmadani*, Armin Darmawan
Department of Industrial Engineering, Faculty of Engineering, Hasanuddin University
Jl.Perintis Kemerdekaan km 10, Makassar 90425, Indonesia
*fachriahdany47@gmail.com
Received: 08th April, 2019; 1st Revision: 26th September, 2019; 2nd Revision: 13th November, 2019; Accepted: 30th April, 2020

Abstract

The study aimed to minimize defective products to improve the production process quality of PT BI by identifying the most types of defects, calculating Defect per Million Opportunities (DPMO) value, suggesting the quality improvement of the Semi Refined Carrageenan (SRC) production process, and calculating Cost of Poor Quality (COPQ) value. The methods used in this research were Six Sigma and the COPQ. The priority improvement based on the Pareto chart was moisture defects with the percentage of damage of 36.9%. The Sigma level of the production process of PT BI was 3.42 with a defect rate of 27,429 DPMO. The analysis on the cause and effect diagram showed that factors affected the occurrence of defective products were error in reading on moisture content, diverse raw material, the wrong method of mixing raw materials prior to production process, and the lack of inspectors of production process. The most influential-dominant factor was the obsolete machine which causes error in reading on moisture content. The company can take preventive and corrective actions to suppress defective products and improve product quality. Based on the calculation of the COPQ, the costs that must be incurred by the company due to defective products was IDR 1,007,690,694.
Keywords: Cost of Poor Quality (COPQ), quality control, seaweed, Six Sigma

Abstrak

Penelitian ini bertujuan untuk meminimalkan jumlah produk cacat sehingga meningkatkan kualitas proses produksi PT BI dengan mengidentifikasi jenis cacat terbanyak, menghitung nilai Defect per Million Opportunities *(*DPMO), *menyarankan perbaikan kualitas proses produksi* Semi Refined Carragenan (SRC) *serta menghitung nilai* Cost of Poor Quality (COPQ). *Metode yang digunakan adalah* Six Sigma *dan* COPQ. *Perbaikan yang diprioritaskan berdasarkan diagram Pareto adalah cacat* moisture *dengan persentase 36,9%. Tingkat* Sigma *dari proses produksi PT BI adalah 3,42 dengan tingkat kecacatan 27,429 DPMO. Analisis diagram sebab akibat menunjukkan bahwa faktor-faktor yang memengaruhi terjadinya produk cacat adalah kesalahan pada pembacaan kadar air, keragaman bahan baku, metode pencampuran bahan baku yang salah sebelum proses produksi serta kurangnya pengawas proses produksi. Faktor dominan yang paling berpengaruh adalah mesin usang yang menyebabkan kesalahan pembacaan kadar air. Perusahaan dapat mengambil tindakan preventif dan korektif untuk menekan jumlah produk cacat dan meningkatkan kualitas produk. Berdasarkan perhitungan COPQ, biaya yang harus dikeluarkan perusahaan akibat produk cacat adalah sebesar Rp1.007.690.694.*
Kata kunci: Cost of Poor Quality (COPQ),, *pengendalian kualitas, rumput laut,* Six Sigma

INTRODUCTION

Nowadays many demands put forward by consumers; however, quality is the only one main thing that plays the biggest role. It is the consumer's main demand. The increasingly market competition also makes the framework of thinking about improving quality not only limited to provide products according to consumer needs but also be accompanied by efforts to reduce all costs to achieve the expected quality (Hansen & Mowen, 2006).

Seaweed is a group of marine plants that has indistinguishable characteristics among the roots, stems and leaves that the whole parts of seaweed are called talus (Ferawati, Widyartini, & Insan, 2014). *Eucheuma cottonii* is one of the types of seaweed that can be cultivated. It is the type of seaweed that is most commonly cultivated for an ingredient in food manufacturing, medicinal mixtures and cosmetics (Rismawati, Salengke, & Tulliza, 2012).

PT BI is a company which engaged in seaweed processing industry. It cultivates seaweed for export, but it has encountered many product defects. Therefore, it has become an absolute demand for PT BI to maintain product quality and respond consumer demands. The purpose of this study is to identify the types of defect in the production process, to calculate the sigma value and the total quality cost in the aspect of Cost of Poor Quality (COPQ), to identify the factors that cause defective products and to provide recommendations and suggestions to minimize the defects and COPQ.

METHODS

Research was conducted in PT BI by data which were obtained from primary data (interview process) and secondary data (number of production unit in 2017-2018 period and data regarding employees' activity of work in the company). Observation was made on processed seaweed products of Semi Refined Carrageenan (SRC) produced by PT BI.

SRC is a carrageenan product with a lower purity level than refined carrageenan for it still contains cellulose which also settles with carrageenan. SRC is commercially made from *Eucheuma cottonii* through a process using alkaline solution (potassium hydroxide/KOH). According to the Research and Development Center for Marine and Fisheries Biotechnology and Product Processing (Balai Besar Penelitian dan Pengembangan Pengolahan Produk dan Bioteknologi Kelautan dan Perikanan, 2013), SRC extracted from *Eucheuma cottonii* seaweed has following contents provided in Table 1. Research flowchart can be seen in Figure 1.

Six Sigma

Six Sigma strategy aims to improve business performance by reducing various unfavorable process variety, reducing production or process failures, suppressing production defects, increasing profit, boosting morale of personnel or employee, and improving product quality at a maximum level (Gaspersz, 2005). It is a very effective

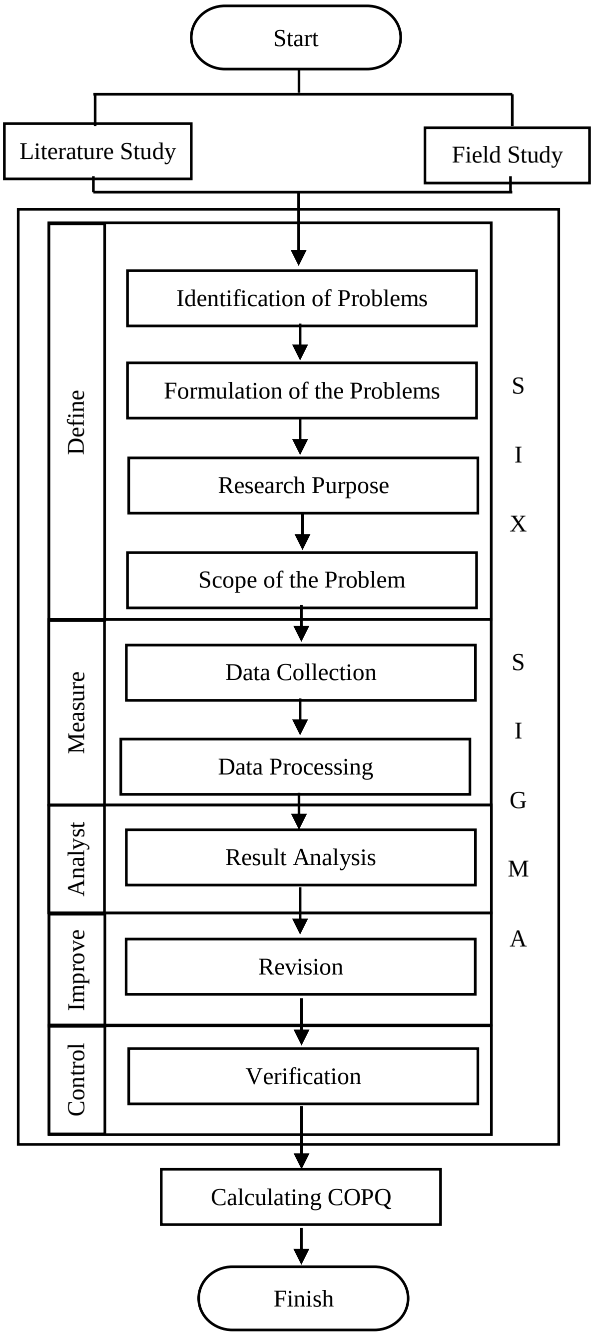

Figure 1. Research Stages

Table 1. Specification of semi refined carrageenan

Parameter	Specification
Yield (%)	38.50
Water Content (%)	5.50
Ash Content (%) wb	0.20
Acid Insoluble Ash Content (%)	0.27
Sulfur Content (%)	17.69
Viscosity (cPs)	250.00
Gel Strength (g/cm^2)	1,009

(Source: Balai Besar Penelitian dan Pengembangan Pengolahan Produk dan Bioteknologi Kelautan dan Perikanan, 2013) principle and technique in implementing quality testing (Pyzdek, 2003). Moreover, it is almost complete in meeting customer requirements as its purpose (Pande, Neuman, & Cavanagh, 2002). Six Sigma, hence, is an important means for production management to maintain, improve and preserve product quality, particularly to achieve quality improvement towards zero defects. Five stages to implement quality improvement using Six Sigma are using the DMAIC method, namely Define, Measure, Analyze, Improve, and Control (Pande & Holpp, 2001). In this study, the five stages of DMAIC analysis at PT BI are described as follow:

Identification of Problems (Define)

Define stage is the goal setting of Six Sigma quality improvement activities. This stage is to define the action plans that must be taken to perform the improvement of each stage of the key business processes (Gaspersz, 2005). At the define stage of a quality problem in the production of SRC, the causes of defective products were defined. Potential causes of defects which were laid on the production of SRC products will as well be explained, namely moisture content, gel strenght and granules content.

Measure

Measure is a logical follow-up to the define stage which will be a bridge to the analyze stage. This step focuses on understanding the performance of the current improved process, as well as gathering all the required data for analysis (Gaspersz, 2005). At the measure stage, control maps is commonly used. By using this tool, it will be known the final result which deviates from the upper limit or the final limit of the product criteria set by the company (Syukron & Kholil, 2013) in the measure, which is as follows:

1. Determination and Ordering Primary Critical To Quality (CTQ)
   At this stage, the management must know the most potential company's internal processes that have great potential to affect the quality of output (CTQ) first. Then the management measures the amount of deviation occurred compared to the quality raw material specified in the CTQ. This means that at this stage we must know the failure or defect occurred in the product or process that we are going to fix.
2. Measurement of Process Stability
   This stage will serve proportion value, CL (Central Line), UCL (Upper Control Limit), and LCL (Lower Control Limit).
   a. Calculating Defect Percentage
   $p = \frac{np}{n}$ ……………..........……………..(1)
   b. Calculating Central Line (CL)
   $CL\ (\underline{p}) = \frac{\text{number of defective product}}{\text{number of production}}$.....(2)
   c. Calculating Upper Control Limit (UCL)
   $UCL = \underline{p} + 3\sqrt{\frac{\underline{p}\,(1-\underline{p})}{n}}$ ……………......(3)
   d. Calculating Lower Control Limit (LCL)
   $LCL = \underline{p} - 3\sqrt{\frac{\underline{p}\,(1-\underline{p})}{n}}$ (4)
3. Measurement of Level of Six Sigma and Defect per Million Opportunity (DPMO)
   a. Calculating DPU (Defect Per Unit)
   $DPU = \frac{\text{Total Defect}}{\text{Total Production}}$ (5)
   b. Calculating DPMO (Defect Per Milion Oportunities) Value
   $DPMO = DPU \text{ x } 1.000.000$ (6)
   c. Level of Six Sigma
   To determine sigma level of production is made by converting DPMO to Sigma value (Syukron & Kholil, 2013).

Analysis of the Cause of Problem (Analyze)

Analyze stage of DMAIC function is to provide suggestion to which priority as an effort to overcome causes of the problem, show the impact of process failures and final products on consumers, describe the causes of failure to the root causes of problems and provide suggestions for improvisation efforts (Tannady, 2015). The category of sources of the defect was identified by a cause and effect diagram.

Suggestions to Maintenance Plan (Improve)

An action plan is implemented in this stage to fulfill Six Sigma quality improvement. The Six Sigma quality improvement team must decide on targets to be achieved, why the action plan is carried out, where the action plan will be carried out, when the plan will be carried out, who is responsible for the action plan, how to carry out the action plan and how much the implementation cost and how big positive benefits implementation of the action plan is (Susetyo & Hartanto, 2014).

Control

Control is the last operational stage in an effort to improve quality based on Six Sigma. At this stage the results of quality improvement are documented and disseminated, successful best practices in improving the process are standardized and disseminated, procedures are documented and used as standard guidelines, and ownership or responsibility is transferred from the team to the owners or processors in charge (Susetyo & Hartanto, 2014).

Cost of Poor Quality

According to Horngren, Datar, & Foster (2009) cost of quality is the cost incurred to prevent low quality products, or is a cost that arises as a result of producing a product that has low quality. Quality control costs are measured in two segments, namely: prevention costs and appraisal costs, while quality control failure costs consist of internal failure costs and external failure costs (Feigenbaum, 1991).

Costs of poor quality are costs due to inability of products and processes to meet the quality standard requirements (Gryna, 2001). According to Gryna (2001) costs of poor quality include:

1. Internal failure costs
   Internal failure costs are costs incurred due to inability to meet customer requirements or needs and due to inefficient processes as well.
2. External failure costs
   External failure costs are the costs of mismatching a product or service following the consumer's product receipt, including costs resulting from lost sales opportunities.

RESULTS AND DISCUSSION

Quality Control by Six Sigma Method

The application of quality control used in this study was the Six Sigma method through five stages of analysis; define, measure, analyze, improve, and control at PT BI in the production of SRC.

Identification of Problem (Define)

Production process of SRC at PT BI was started from *E. Cottoni* seaweed weighing, washing, cooking (softening process), rewashing twice, cutting, rewashing, drying, sorting, milling, and packing. The results of observation in the production line and interview with quality department of PT BI showed the frequently occurred defects was unsuitable moisture and gel strength as well as excessive granules content. The standards used can be seen in Table 2.

Table 2. Content specification standard of semi refined carrageenan

Defect type	Assessment Standard Based on SNI No. 2690.1:2009	BBP4BKP	PT BI
Moisture Defect (%)	30	12	<15
Gel Strength Defect (g/cm^2)	1,000	1,009	700
Granules Defect (%)	5	1	1

Table 3. Number production defects of semi refined carrageenan in 2017 to 2018

Defect Type	Defect amount (Kg)	Percentage (%)	Cumulative (%)
Moisture Defect	3,325	39.6	39.6
Gel Strength Defect	2,650	31.5	71.1
Granules Defect	2,425	28.9	100.0
Total	**8.400**	**100,0**	

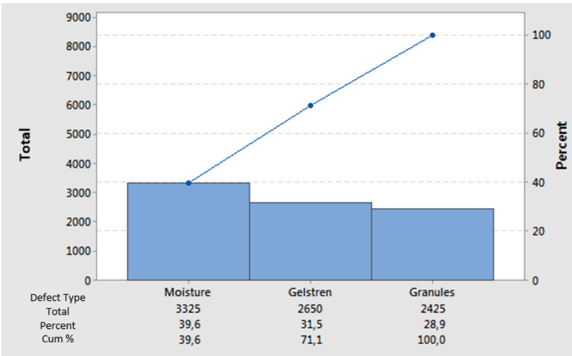

Figure 2. Pareto Chart of PT BI Production Defect

Measure

Measure stage is intended for obtaining information about value of strategic measurement for further stage. Steps to calculate are as follow:

1. Determination and Ordering CTQ Priority
   Based on the data obtained, potential Critical to Quality (CTQ) which has been met by PT BI were showed in Table 3. Pareto chart (Figure 2) shows frequency of the most dominant defects namely moisture defect of 39.6%, gel strength defect of 31.5% and granules defect of 28.9%. Pareto chart does not only show relative size of the quality rating, but also as helpful visual means

Blocher, Stout, & Cokins (2011). It, moreover, serves in identifying the main cause of low quality so as the management is able to focus on quality improvement efforts which correspond to the most influential aspect.

2. Measurement of process stabilization
   According to the calculation, then, further action was conducted to make control chart p as in Figure 3 and Figure 4. Criteria used in p-chart are:
   a. If P< LCL, it means the samples came down outside lower control limit (LCL) then inspect its cause.
   b. If LCL < P > UCL, it means that all samples are within control limits and it is called they act normally or having good process capability.
   c. If P > UCL, it means that samples came out outside upper control limits (UCL) or it is classified as low process capability then inspect its cause and take corrective action through performance improvement of production process.

   According to the figure, it is showed that P (proportion defective) is mostly outside control limits, then it can be said that process capability did not run smoothly/low so that it is not able to declare process capability has fulfilled the specification of expected tolerance limit. If there is no data off the upper control limit (UCL) or lower control limit (LCL) as well as data plots did not show any deviation indicator then the process is in under control. If the data off the control limits, on the contrary, then it is called uncontrolled process, so it requires corrective actions so as the defective products can be prevented. Measurement data that caused uncontrolled process or extreme data needs to be eliminated accordingly in order to continue calculation of process capability. The extreme data in question are data of March 2017, August 2017, November 2011, February 2018, July 2018 and November 2018. After eliminating extreme data, recalculate process stability is further step to obtain process data that is within control limits.

   Based on the p control map in Figure 4, it shows that the process is in a stable state for they are within control limits. As long as the points are within control limits, the process is considered controlled, if the data pattern is random, on the contrary, it can be said to be uncontrollable.

3. Measurement Six Sigma Level and Defect per Million Opportunity (DPMO)
   According to calculation in the production department of PT BI especially SRC production, it has sigma level of 3.42 with defective probability of 27.429 for one production. This is likely to be a big loss if it is not handled because more failed products in the production process, surely, will result production costs overrun.

<u>Analysis Cause of Problem (Analyze)</u>

In this study, Fishbone Diagram was used (Figure 5) to determine the cause of the defects. If the causal relationship of the problem is known, problem-solving actions are easy to determine. Causes of the problem are grouped into 5 main factors, i.e., humans, machines, materials, methods and environment.

1. Human
   Defective product which is usually found in the production process was due to lack of worker (Inspector) who performs checking process so that it frequently experienced errors in recording moisture content.

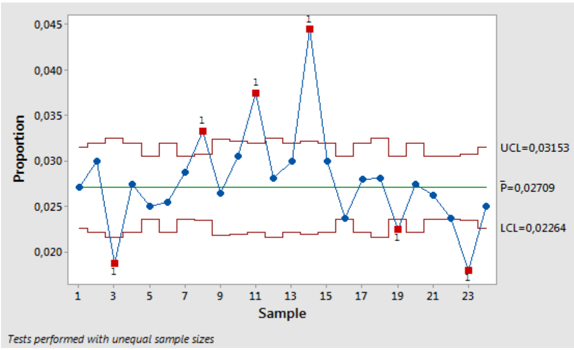

Figure 3. Control Chart (P - Chart)

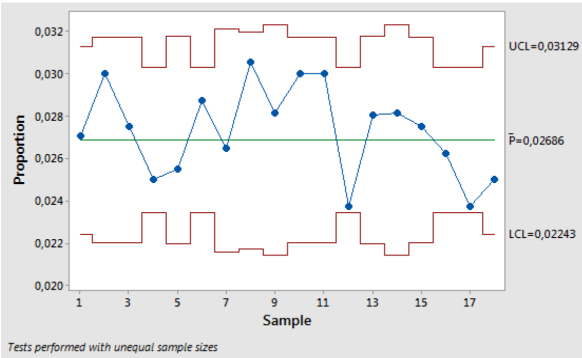

Figure 4. Control Chart (P - Chart) Revision 1

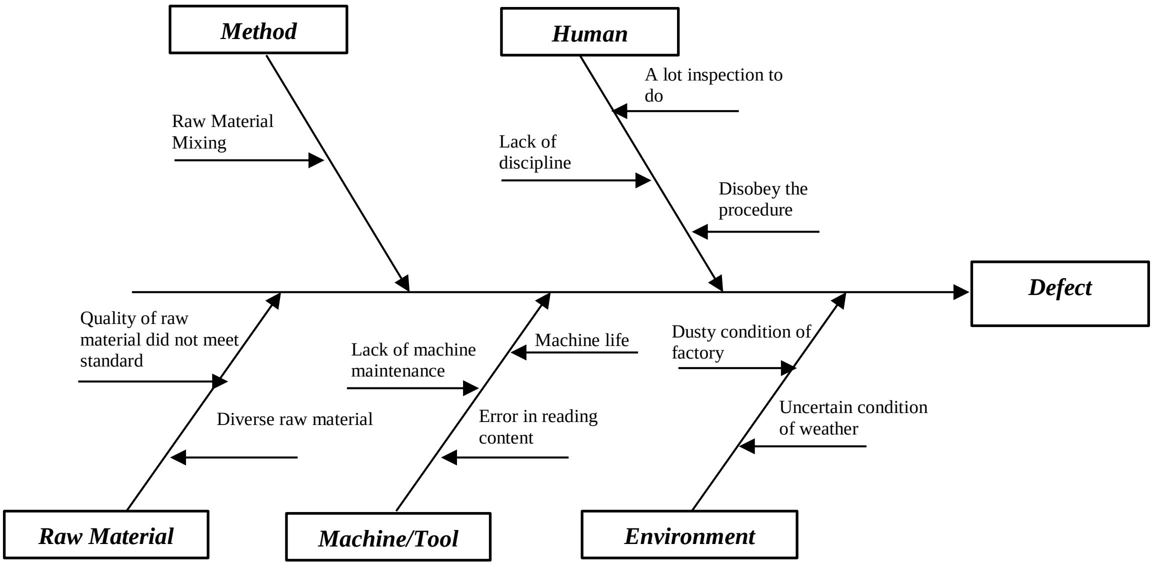

Figure 5. Fishbone Diagram of Moisture, Gel Strength and Granule Defect

2. Machine
   Machines are the main tools to support production process. Problems of machine that cause product defects was machine made errors in reading the gel strength and moisture content. This is due to the lack of regularity of maintenance process and its old life.
3. Material
   Main factor that caused defective product in the production process of PT BI was the great number and type of materials which mostly used that resulted different content of gel strength and moisture. By the great number of materials used in one production, hence, it was difficult for the machine to read the content of these materials.
4. Method
   Using good working method will definitely reduce number of defective products. And if it uses poor working method, on the contrary, will result higher probability of defective product produced. In the production process, all of materials (seaweed) that processed into flour will be mixed so that it was sometimes resulted change in moisture content which did not match to production standard.
5. Environment
   Company's neighborhood that directly or indirectly affected the company in general and the production process in particular.

Suggestion to Improvement Plan (Improve)

It is required to set a recommendation or suggestion for improvement after knowing the cause of defect of SRC product. The improvement to suppress level of defective product are provided in Table 4.

Cost of Poor Quality

The following is the result of identification of various costs incurred by PT BI in 2017-2018 for activities related to quality in producing products that meet specified quality standards. Classification on quality cost of the company is according to concept of quality cost category (Gryna, 2001).

Cost of control in 2018 according to the Table 5 experienced reduction of IDR 1,950,000 it is, moreover, the result of difference from the total cost of control in 2017 of IDR 21,203,571 and the total cost of control in 2018 of IDR 19,253,571. COPQ experienced contrarily, it increased IDR 1,007,690,694 in 2018 i.e. the difference of the total of COPQ in 2017 IDR 516,450,193 and total of COPQ in 2018 that is IDR 1,524,140,887.

The increase of COPQ considered as company's incapability to minimize number of defective unit through quality improvement activities that increased cost of control. The reduction of costs of control incurred, however, was more than the increase of COPQ obtained. The reduction of failure cost, on the other hand, should be more than the increase of cost of control; hence, cost incurred by company could eventually be more efficient.

Table 4. Suggestion to improvement

Element	Causative Factor	Recommendation
Raw Material	1. Quality of material that did not meet standards 2. Diverse kind of material and in a great number 3. The temperature does not fit to the conditions either at the storage or in the production process	1. Strictly sorting the raw materials that get in the company 2. Record and label each seaweed; mass, type, origin, number, the date and store it according to its type 3. Install thermostat to maintain temperature of each production process.
Method	1. Laboratory procedure which is not updated 2. Lack of Sorting process and washing. 3. Incomplete drying process	1. Update laboratory procedures 2. Use water spray to improve washing effectiveness. After soaking in water, the cage which was filled with seaweed then remove and spray it from the side to reduce water usage. 3. Improve dirt separation process (sand, gravel, etc.) by installing screen separator with vibration. 4. Replacing sun drying with mechanical drying by using a rotary drum will increase work efficiency because mechanical drying does not depend on weather conditions so that the drying process can be completed in 1 day.
Tools/ Machine	1. Machine life 2. Lack of machine maintenance 3. Error in reading content	1. Check machine settings periodically and perform calibration 2. Repair the damaged machines, perform maintenance on machines intensively and continuously 3. Operate the machine consecutively or add more machine
Human	1. Disobey the rule 2. Lack of discipline 3. Many inspections were carried out	1. Provide training and warning to workers so they do not make any mistake 2. Conduct intensive inspections of employees by supervisors
Environment	1. Dusty condition of factory 2. Uncertain weather	1. Install the cover and reservoir around the output of milling machine to catch SRC that float and to not scattered on the floor so that it can be recovered 2. Install a control parameter 3. Use automatic machine for drying process

Table 5. Total and percentage of quality cost

	Quality Cost	2017	2018	2017	2018
Cost of Control	Prevention Cost	IDR 14,507,143	IDR 12,557,143	2.61%	0.80%
	Appraisal Cost	IDR 6,696,429	IDR 6,696,429	1.21%	0.43%
Cost of Poor Quality	Internal Failure Cost	IDR 516,450,192	IDR 1,524,140,887	96.18%	98.77%
	External Failure Cost	IDR 0	IDR 0	0%	0/%
Total		IDR 537,653,764	IDR 1,524,140,887	100%	100%

COPQ proportion of the total of quality cost of the company is presented at Table 5. According to the table, the proportion of COPQ that consists of internal and external failure cost were up to 90% of the total quality cost. It is showed that the company has opportunity to minimize COPQ by performing quality improvement activities that will eventually increase cost of control (Hansen & Mowen, 2006).

If Six Sigma was implemented, it would be very influential for PT BI. It was proven by availability of substantial COPQ. The lower the COPQ value obtained then indicates relatively small failure management costs in the process as well. This means that the process is able to produce good quality products, and the higher achievement of a sigma level of the process.

CONCLUSION

Types of defect laid on the production process of PT BI in 2017 and 2018 were moisture content, ash content, gel strength, sulfur content, viscosity and granules content. The research, however, only focused on three types of defect namely moisture content, gel strength content and granules content since flour composition produced did not represent the content level it should. Defect per million opportunities (DPMO) values of PT BI Mills in 2017 and 2018 was 6,100 kg of defective products per one million productions. Currently, the company has sigma value of 3.42 it means there are approximately 27,429 of defective products in one million productions, it, moreover, is categorized good compared to industry standard in Indonesia i.e. 308,537 of defective products per one million productions. Besides, the COPQ company must incur due to defective products in 2017 was IDR 16,450,193 and IDR 1,524,140,887 in 2018.

Factors affected the occurrence of defective products were error in reading on moisture content, diverse raw material, the wrong method of mixing raw materials prior to production process, and the lack of inspectors of production process. The most influential-dominant factor was the obsolete machine which causes error in reading on moisture content. The improvement to reduce the level of defective products should apply to the most dominant factor that contributed to the cause of defect. The machine should have a good maintenance and calibration to maintain it function optimally. Paying attention to COPQ can increase the company's profit so that it has an advantage in competing with its competitors.

References

Balai Besar Penelitian dan Pengembangan Pengolahan Produk dan Bioteknologi Kelautan dan Perikanan. (2013). *Semi Refined Carrageenan (SRC) dari Euchema cottonii*. Jakarta: Badan Penelitian dan Pengembangan Kelautan dan Perikanan.

Blocher, E. J., Stout, D. E., & Cokins, G. (2011). *Manajemen Biaya Penekanan Strategis*. Jakarta: Salemba Empat.

Feigenbaum, A. V. (1991). *Total Quality Control* (3rd ed.). New York: McGraw-Hill Education.

Ferawati, E., Widyartini, D. S., & Insan, I. (2014). Studi komunitas rumput laut pada berbagai substrat di perairan Pantai Permisan Kabupaten Cilacap. *Scripta Biologica*, *1*(1), 55–60. https://doi.org/10.20884/1.sb.2014.1.1.25

Gaspersz, V. (2005). *Total Quality Management*. Jakarta: Gramedia Pustaka Utama.

Gryna, F. M. (2001). *Quality Planning and Analysis: From Product Development through Use* (4th ed.). Boston: McGraw-Hill.

Hansen, D. R., & Mowen, M. M. (2006). *Cost Management: Accounting and Control* (5th ed.). Mason: Thomson South-Western.

Horngren, C. T., Datar, S. M., & Foster, G. (2002). *Cost Accounting: A Managerial Emphasis* (11th ed.). New Jersey: Prentice Hall.

Pande, P., & Holpp, L. (2001). *What Is Six Sigma?* Boston: McGraw-Hill Education.

Pande, P., Neuman, R. P., & Cavanagh, R. R. (2002). *The Six Sigma Way (Bagaimana GE, Motorola, dan Perusahaan Terkenal Lainnya Mengasah Kinerja Mereka)*. Yogyakarta: Andi Offset.

Pyzdek, T. (2003). *The Six Sigma Handbook: The Complete Guide for Greenbelts, Blackbelts, and Managers at All Levels* (Revised an). New York: McGraw-Hill.

Rismawati, Salengke, & Tulliza, I. S. (2012). *Studi Laju Pengeringan Semi-Refined Carrageenan (SRC) yang Diproduksi dari Rumput Laut Eucheuma cottonii dengan Metode Pemanasan Konvensional dan Pemanasan Ohmic*. Skripsi. Program Studi Keteknikan Pertania. Jurusan Teknologi Pertanian. Universitas Hasanuddin. Makassar.

Susetyo, J., & Hartanto. (2014). Analisis pengendalian dan perbaikan kualitas dengan pendekatan Six Sigma dan Kaizen. *Prosiding Seminar Nasional Aplikasi Sains & Teknologi (SNAST)*, B-189-B-198. Yogyakarta: Institut Sains & Teknologi AKPRIND.

Syukron, A., & Kholil, M. (2013). *Six sigma: Quality for Business Improvement*. Yogyakarta: Graha Ilmu.

Tannady, H. (2015). *Pengendalian Kualitas*. Yogyakarta: Graha Ilmu.